Monitoring Hydropatterns in South Florida Ecosystems Using ERS SAR Data

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ABSTRACT

This paper summarizes the results of an ongoing study of ERS SAR imagery collected over the southern Florida, an area containing numerous wetlands. This study showed that the signatures from the wetlands in this region observed in the ERS SAR imagery vary widely throughout the year. The seasonal differences in these signatures are shown to be primarily due to variations in water levels.

Keywords: wetlands, flooding,, ERS SAR, FloridaEverglades, Big Cypress National Preserve

INTRODUCTION

Southern Florida contains one of the largest complexes of freshwater wetlands found anywhere in the world. While the Everglades is the largest and most noteworthy of these systems, numerous other wetlands types are indigenous to this region, such as the wet marl prairies and cypress forests found in the Big Cypress National Preserve located northwest of the Everglades. Most wetland ecosystems in southern Florida have been heavily impacted by human activities, with the temporal patterns of flooding or inundation partially or entirely disrupted. Even though the scientific community has long recognized the importance of these wetlands, it has only been recently that the general public and policy making communities have begun to accept the need for intensive wetland restoration and mitigation.

A key challenge facing the scientific and management communities is monitoring the temporal and spatial patterns of flooding in wetland ecosystems, e.g., the hydropattern. While the remote sensing community has long recognized that longer-wavelength SARs (such as Seasat and JERS-1) are capable of monitoring flooding in forested wetlands (), it has only been recently recognized that the ERS SAR can be used to detect and monitor flooding in wetlands dominated by herbaceous vegetation (Morrissey et al. 1994; Kasischke et al. 1997). Since a high percentage of the wetlands in southern Florida are non-wooded, it has been realized that ERS offers a unique means for monitoring flooding in this region (Kasischke and Bourgeau-Chavez 1997).

In this paper, we review recent research using ERS SAR imagery to monitor the patterns of flooding within the Everglades National Park (ENP) and the Big Cypress National Preserve (BCNP), both of which are located in southern Florida. First, we present examples of ERS SAR imagery illustrating dramatic variations in image intensity over both the ENP and BCNP and discuss the sources of these variations. Next, we illustrate how color compositing of different dates of ERS SAR data can be used as an effective tool for monitoring changes in water levels and soil moisture conditions.

ERS SAR IMAGERY OF SOUTH FLORIDA

Figure 1 presents a series of ERS SAR images collected over the south Florida region during late 1995 and 1996. For references purposes, Figure 2 presents the major geographic features of the imaged area and Figure 3 summarizes monthly precipitation during this time period.

Southern Florida is located within the tropics and has distinct wet and dry seasons. From Figure 3, it can be seen that the 11 December 1995 to 30 April 1996 images were collected during the dry season, while the 4 June to 17 September images were collected during the wet season. Figure 3 shows that the precipitation during the wet season in 1996 was slightly below the average for the past 30 years. Overall, there is an increase in radar image intensity as the dry season progresses and a decrease in image intensity as the wet season progresses. There are areas within the images where the opposite trend exists.

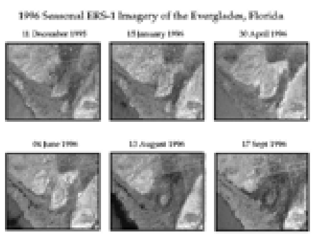

Figure 1. ERS SAR Images of Southern Florida (Images Copyright European Space Agency 1995, 1996

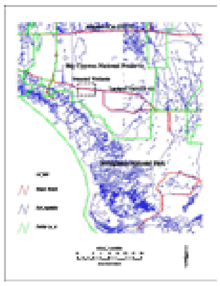

Figure 2. Schematic Diagram Illustrating the Major Geographic Features of the Areas within the ERS Images in Figure 1

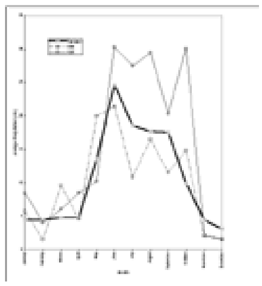

Figure 3. Average Monthly Precipitation for Southern Florida

To understand why these image intensity variations occur, one needs a basic understanding of the sources of microwave or radar scattering from vegetated surfaces. One of the major sources is direct scattering of energy from the vegetation. Up until a certain point, as the density and biomass of a canopy increases, so does the radar scattering from that vegetation. A certain amount of the microwave energy passes through the vegetation, however, and reaches the ground surface. Here, the energy is either absorbed, scattered back to the radar system or is scattered in a forward direction away from the radar. For unflooded surfaces, the degree of scattering from the ground is directly proportional to soil moisture. If a layer of water covers the ground surface (which occurs in a flooded wetland), then all the radar energy is reflected away from the radar receiver. A third scenario for a radar signature exists if a wetland contains woody vegetation (trees or shrubs). In this case, the microwave energy that is scattered away from the radar transmitter is intercepted by tree branches or boles, and reflected back to the radar.

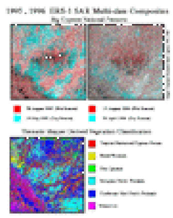

Figure 5. Two-Color Composite ERS Images and Vegetation Map Over Big Cypress National Preserve

In summary, there are three potential sources of scattering from a vegetated surface: (1) direct scattering from the vegetation canopy; (2) direct scattering from the ground; and (3) multiple reflection scattering from between the ground and vegetation.

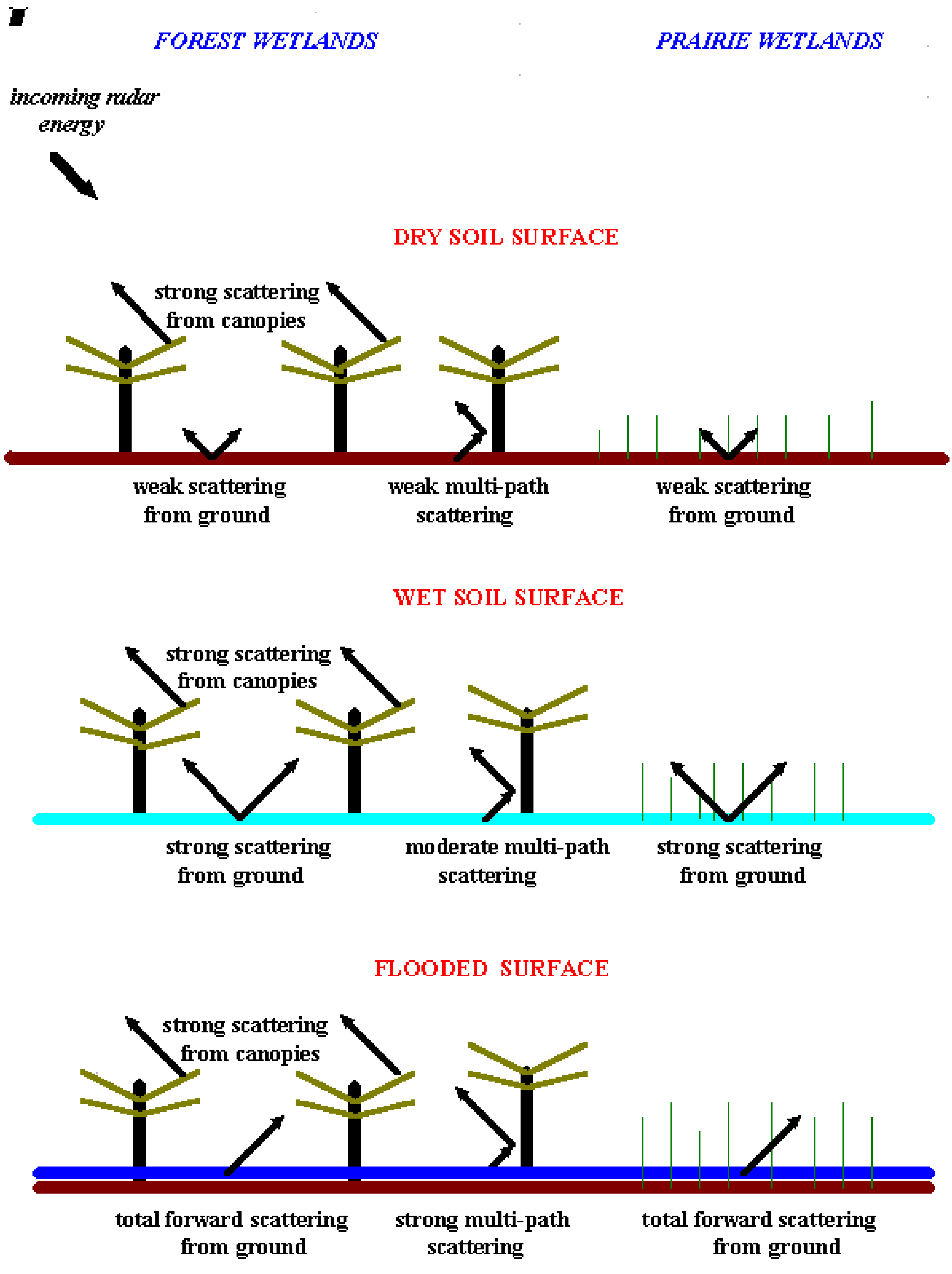

Figure 4. Illustration of the effects of vegetation, soil moisture, and flooding on ERS radar signatures.

Figure 4 illustrates the types of scattering which occurs in two different wetland types found in southern Florida: dwarf cypress and wet marl prairies. This diagram illustrates the sources of radar scattering as function of variations in soil moisture and flooding. Relative to a dry ground surface, wet soils would increase the radar signature from both wetland types. In contrast, relative to the wet soil surface, a flooded surface would: (1) increase the radar signature from the dwarf cypress because of the enhance ground-to-tree scattering but; (2) reduce the radar signature in the wet marl prairie because of the total reflection of the microwave energy away from the radar.

ANALYSIS OF A TWO-DATE ERS SAR IMAGES

Figure 5 presents two color color-composite images generated from ERS SAR imagery collected at the end of the dry season (April/May) and towards the end of the wet season (August). The two images presented in Figure 5 were generated from data collected in 1995 and 1996. Note from Figure 3 that the rainfall during the wet season of 1995 was significantly greater that during the same time period in 1996.

These images are from an area which has two dominant vegetation covers: prairie wetlands and cypress/hardwood forests. The normal pattern of inundation in these two wetland types is for there to be standing water during the wet season, and very little or no standing water, but very moist soils during the dry season. This normal inundation pattern would result in the forested stands having brighter signatures during the wet season than in the dry season because of the enhanced multiple-bounce scattering from the flooded surface. In contrast, the prairie wetlands would have a much brighter signature during the dry season because of the higher direct scattering from the moist soil.

The color-composite images in Figure 5 were generated by assigning the dry season image the color blue and the wet season image the color red. Thus, forest stands with a normal inundation pattern appear red in the 1995 composite image in Figure 5, while prairie wetlands appear blue.

Some of the prairies adjacent to the Taimiami Trail do not exhibit a color associated with the normal inundation pattern in the 1995 composite image in Figure 5. In particular, there are prairie wetlands on the north side of the road which have a "dark" signature and on the south side of the road which have a red signature. These variations from normal are thought to be caused by the road itself. On the north side, a borrow pit runs continuously parallel to the road, forming a canal. This canal serves to drain the prairie wetlands north of the road, and significantly reduces the soil moisture in these prairies during the dry season. These dry soil would have a darker radar signature compared to areas with wet soils. Because the road blocks the normal north-to-south flow of surface water during the wet season, the prairies immediately to the north of the road flood during the wet season, as do prairies not affected by the road. Thus, the prairies north of the road have a dark signature in both the wet and dry seasons, resulting in a dark signature on the composite image in Figure 5. The blocking of normal surface flow affects the prairies to the south of the road as well. Because of the blocking of the normal surface flow in the wet season, these areas tend to become: (1) drier than normal prairies during the dry season; and (2) do not become flooded during the wet, but have wet soils at this time. Thus, these areas have a brighter signature (from wet soils) during the wet season, resulting in the red signatures on the composite radar image in Figure 5.

The absence of the extensive blue signatures in the wetland prairies in the 1996 composite ERS SAR image indicates that these wetlands most likely did not flood during that year's wet season. The almost white signature in many of the prairie wetlands indicates these areas had wet soils in both the wet and dry seasons. The darker red signatures in some of the wetland prairies, especially along the Taimiami Trail, are indicative of dry soils during the dry season and moist, but unflooded soils during the wet season. Comparison of the two SAR composite images in Figure 5 clearly shows that inter-seasonal variations in hydropattern can be detected using ERS data.

SUMMARY

This study has shown that the imaging radar onboard the ERS satellite is uniquely suited to monitor variations in surface inundation and soil moisture in several different wetland ecosystems in southern Florida. Studies are currently underway to explore the utility of ERS radar imagery, as well as that collected by the Radarsat satellite, to monitor patterns of inundation in all the different wetland communities in this region. Because of its ability to monitor large areas in a single image, ERS radar imagery provide a valuable resource monitoring tool which compliments efforts to monitor water levels using point-source measurements. In particular, this technology may be quite appropriate for: (1) identifying areas where human built structures have influenced the natural flow of water; and (2) monitoring the effects of efforts specifically designed to restore the natural flow of surface water within wetland ecosystems in this region.

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